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# Ultrasound and CBCT analysis of blood flow and dimensions of the lingual vascular canal: A case control study

Lakha, Tabrez ; Kheur, Mohit ; Mühlemann, Sven ; Kheur, Supriya ; Le, Bach

Abstract: Objective To assess the correlation between the diameter of the mandibular lingual vascular canal (MLVC) as determined on CBCT examination to blood flow and arterial diameter as determined by ultrasound Doppler analysis (USG) in dentate and edentulous patients. Methods 20 subjects were equally distributed into two groups based on the status of their dentition. Group 1 included dentate subjects (DE) and Group 2 included edentulous subjects (ED).The subjects from both the groups underwent CBCT scan for the assesement of the diameter of the MLVC.Similarly, USG was done to assess the diameter of the sublingual artery anastomosis and blood flow in the anterior mandible. Data was analysed using Karl Pearson's Correlation coefficient test and Student's unpaired 't' test. Results Irrespective of the status of the dentition and age, a positive correlation was noted between the diameter of foramen on CBCT examination and the diameter of anastomosing artery as studied by the USG (r = 0.290).Similarly, a positive correlation was observed between the diameter of foramen on CBCT and the volume of blood entering the mandible (r = 0.447).A positive correlation (r = 0.138) was observed between the diameter of the anastomosing artery and the volume of blood entering the mandible. Conclusion The anterior mandible has a rich vascular supply independent of age and status of the dentition.The dimensions and location of MVLC could be assessed on a CBCT prior to implant placement so that the operating surgeon has an idea about the vascularity of the region. Further studies with higher sample size should be undertaken to confirm these findings.

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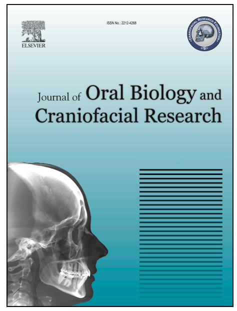


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**Title page**

Title: Ultrasound and CBCT analysis of blood flow and dimensions of the lingual vascular canal: A Case Control study

Running title: Determination of vascularity in the mandible.

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# Ultrasound and CBCT analysis of blood flow and dimensions of the lingual vascular canal: A Case Control study

Abstract:

Objective: To assess the correlation between the diameter of the mandibular lingual vascular canal (MLVC) as determined on CBCT examination to blood flow and arterial diameter as determined by ultrasound Doppler analysis (USG) in dentate and edentulous patients.

Methods: 20 subjects were equally distributed into two groups based on the status of their dentition. Group 1 included dentate subjects (DE) and Group 2 included edentulous subjects (ED).The subjects from both the groups underwent CBCT scan for the assesement of the diameter of the MLVC.Similarly, USG was done to assess the diameter of the sublingual artery anastomosis and blood flow in the anterior mandible. Data was analysed using Karl Pearson's Correlation coefficient test and Student's unpaired 't' test.

Results: Irrespective of the status of the dentition and age, a positive correlation was noted between the diameter of foramen on CBCT examination and the diameter of anastomosing artery as studied by the USG (r=0.290).Similarly, a positive correlation was observed between the diameter of foramen on CBCT and the volume of blood entering the mandible (r=0.447).A positive correlation (r = 0.138) was observed between the diameter of the anastomosing artery and the volume of blood entering the mandible.

Conclusion: The anterior mandible has a rich vascular supply independent of age and status of the dentition.The dimensions and location of MVLC could be assessed on a CBCT prior to implant placement so that the operating surgeon has an idea about the vascularity of the region. Further studies with higher sample size should be undertaken to confirm these findings.

**Key words:** midline lingual vascular canal, blood velocity, blood volume, hemmorhage.

Conflict of interest statement: The authors declare no conflict of interest.

**Introduction:**

The anterior mandible is considered a favorable site for implant placement with reported success rates of up to 95%.[1] Implant surgeries are routinely performed in this region, specifically for single , two or four implant supported overdentures. The inter- foraminal region of the anterior mandible is also considered as a donor site for harvesting of autogenous bone.

Even though anterior mandible is considered safe for implant placement, the literature reports rare and hemorrhagic episodes encountered in this region during implant placement.[1,2] A thorough review of complications of implant placement in the anterior mandible performed by Kalpidis et al concluded that unnecessary insertion of long implants should be avoided specifically in cases of the atrophic mandible as it can lead to hemorrhage.[3] Similarly a review by Kusum et al presented 21 cases of haemorrhagic episodes in this region, 17 out of 21 cases required emergency treatment due to air-way obstruction.[4]

Hemorrhage in the anterior mandible occurs due to the accidental perforation of the lingual cortex with resultant injury to the sublingual artery.[1,5] The sublingual artery is a branch of the lingual artery, the branches of which supply the floor of the mouth and enter the mandible through the lingual foramen situated in the midline of the mandible.[6]

The contents of the lingual foramen is a focus of controversy and debate. According to Ennis et al, the lingual foramen transmits a branch of the incisive artery to anastomose with the sublingual artery.[7] Another study states that the content of this foramen is a neurovascular bundle formed by filaments of the mylohyoid nerve.[8] McDonnell et al reports, that the content of the lingual foramen is an artery, resulting from an anastomosis of the sublingual branches of the right and left sublingual arteries.[9] These findings were reaffirmed by Rosano et al, who evaluated the blood supply in cadavers and concluded that the anterior mandible derived its blood supply from anastomosis of sublingual arteries at the entrance of the lingual foramen.[10]

Computed tomography is considered a reliable imaging method that allows visualization of bony canals in which the examined vessels course through the mandibular bone.[11] However, dynamic features of both vascular architecture and blood flow in real time can only be assessed by Doppler ultrasonography.[12]

Several studies report the diameter, frequency and the contents of these lingual foramina or the mandibular lingual vascular canals (MLVC) and the course of the sublingual artery anastomosis.[11-14] To determine the risk of bleeding during implant placement, it is important to assess the volume of blood entering the mandible through the lingual foramen. The blood flow in real time can only be evaluated using Doppler ultrasonography which is not commonly used as a diagnostic aid prior to implant surgeries.

No study in the literature has correlated the volume of blood entering the mandible and the diameter of the sublingual artery anastomosis (as evaluated by Doppler ultrasonography) to the dimensions of the mandibular lingual vascular canal as observed on the CBCT.

This study aims to assess the correlation between the diameter of the mandibular lingual vascular canal (MLVC) as determined on CBCT examination to the blood volume , velocity and arterial diameter as determined by ultrasound Doppler in different age groups.

Hypothesis –Diameter of the lingual foramen studied on CBCT may correlate with diameter of the artery observed on doppler ultrasonography.

## Material and Methods:

### Study Design:

The present study was designed as a case control study and was conducted at the Department of Prosthodontics and Implantology at M.A.Rangoonwala College of Dental Sciences and Research Center , Pune. Ethical approval was obtained from the Institutional Review Board of Maharashtra University of Health Sciences (Adm/7505-A/2016). Informed consent was obtained from all the patients prior to their enrolment in the study. All procedures were carried out in accordance with the principles set out in the Helsinki Declaration for human experimentation.

*Inclusion and Exclusion Criteria:*

Patients presenting for dental treatment in the clinic were enrolled in this study. The selected patients were either edentulous with over 5 years of edentulism (Group ED, n=10) or dentate (Group DE, n=10) showing presence of all teeth up to 1$^{st}$ mandibular molars. Patients with any blood or metabolic disorders, such as diabetes and vitamin D deficiency, or with a history of radiotherapy were excluded from the study.

*CBCT Examination:*

All patients received a limited CBCT PSR9000N (i-CAT, Kavo, Germany). The exposure conditions were 70–80 kV, 6– 10 mA, 13.3 or 6.7 s. Axial images were transmitted to a personal computer in the digital imaging and communications in medicine (DICOM) format and reconstructed into multiplanar reconstruction images using the DICOM viewer. Axial and coronal sections were evaluated to identify the presence and position of the MLVC. The horizontal diameter of the MLVC (mm) was measured at the entrance to the anterior mandible in the axial section (Fig 1 and Fig 3). The presence of MLVC can also be appreciated in the sagittal section (Fig 2 and Fig 4).

Doppler analysis:

For the ultrasound Doppler analysis (HD3000 Unit, ATL, Bothell, WA) of the anterior mandible, the patients were positioned with the head in an overextended position to the posterior. All measurements were performed by an experienced and calibrated radiologist. An 8 to 12 Mhz linear high-resolution superficial transducer with a 60-degree insonation angle was used to evaluate the location of the sublingual arteries and the blood volume. Initially right and left branches of sublingual arteries were identified, and sublingual artery anastomosis was traced following the course of the artery as it entered the mandible as reported by lustig et al.[14] The volume (ml/min) and velocity (cm/s) of blood flow entering the mandible and the diameter (mm) of the anastomosing artery were determined (Fig 5 and Fig 6).

Variables:

In this study the primary outcome variables were the diameter of the MLVC and volume of blood entering the mandible. The secondary outcome variable were the velocity of the blood and diameter of the anastomosing artery. The effect confounders such as age was also analysed.

Data Evaluation:

Data obtained was compiled on a MS Office Excel Sheet (v 2010, Microsoft Redmond Campus, Redmond, Washington, United States). Data was subjected to statistical analysis using Statistical package for social sciences (SPSS v 21.0, IBM). Student’s ‘t’ test was performed to compare the outcome variables between the groups. Karl Pearson's Correlation coefficient test was performed to analyze the correlation between the diameter of the MLVC and the blood flow measures. For all the statistical tests, $P<0.05$ was considered to be statistically significant, keeping $\alpha$ error at 5% and $\beta$ error at 20%, thus giving a power to the study as 80%.

This study followed the guidelines established Strobe Statement (http://www.strobe-statement.org)

## Results

The mean age of patients involved in the study was 61.9 $\pm$ 5 years in the group ED (6 females, 4 males) and 49 $\pm$ 5 years in the group DE (5 females, 5 males). The presence of MLVC was noted in the all the subjects irrespective of the age and status of the dentition. Positive correlation was observed between the diameter of the MLVC observed on the CBCT and the anastomosing artery irrespective of the groups (Fig 7, Table 1). A statistically significant positive correlation was observed between the diameter of the lingual foramen observed on the CBCT and the volume and velocity of the blood flow as recorded in the doppler ultrasonography (Table 1).

On intergroup compassion, a strong positive correlation was noted in the group DE (r=0.62) between the diameter of the MLVC and the volume of blood compared to the group ED ( r=0.38) (Table 2 & 3). Similarly, the correlation between the diameter of the MLVC and the velocity of the blood flow was stronger in the group DE (r= 0.59) compared to the group ED ( r=0.39) (Table 2 & 3). The differences between the group DE and ED were statistically insignificant ($p>0.05$). Furthermore, the correlation between the diameter of the anastomosing artery as seen on the doppler ultrasonography and the diameter of the MLVC was stronger in the DE group (r=0.56) compared to the ED group (r=0.27).

The mean diameter of the MLVC was 0.76 $\pm$ 0.2 mm (ED group) and 0.85 $\pm$ 0.1 mm (DE group) and the mean diameter of the anastomosing artery was 0.88 $\pm$ 0.2 mm (ED group) and 0.82 $\pm$ 0.2 mm (DE group). The velocity and volume of blood was greater in the DE group (15.1 cm/sec and 8.90 ml/min) as compared to the ED group (13.8 cm/sec & 8.3 ml/min). No statistical significant difference was noted for these parameters between the DE and ED groups ($P$>0.05) (Table 4, Fig 8).

## Discussion:

The purpose of the study was to asses the correlation between the diameter of the MLVC as measured on the CBCT to the blood flow entering the mandible as analysed in Doppler ultrasonography in dentate and edentulous patients.

The present clinical study demonstrated that in edentulous patients the correlation between the diameter of the MLVC and the blood flow is weak, whereas these correlations are stronger in dentate patients. Therefore, the null hypothesis was accepted.

The edentulous mandible with sufficient bone is classified as a 'Straightforward' condition for implant placement by ITI treatment guidelines (SAC classification). Tomlijenovic et al in a recent systematic review reported 27 cases in which implant surgery was associated with a severe bleeding. Interestingly more than 2 out of 3 such cases were reported in the anterior mandible[15]. The anatomy of the anterior mandible seems to play a crucial role in the cause of these incidents. Perforation of the lingual artery during implant placement can lead hemorrhagic incidents. Even when the lingual cortical plate is not perforated, the sublingual artery running within the bone may be injured during implant placement[15,16]. This complication can lead to the formation of a large hematoma in the floor of the mouth which in turn can result in airway obstruction[16,17].

*Presence of MLVC:*

The presence of the lingual vascular canal (MLVC) and the vascularity of the interforamina region have been assessed in the literature[14]. Kilic et al evaluated 200 CBCT scans for the presence of mandibular lingual vascular canal (MLVC) and reported that the typical location of this canal was the midline region of the mandible[13]. Similarly, Longoni et al reported that a single midline vascular canal is consistently present in the anterior mandible and a CT examination should be performed prior implant surgery to avoid the risk of hemorrhage during implant surgery[16]. Mc Donnel et al evaluated dry specimens of 314 mandibles and noted that the lingual foramen in the mandibular midline was a consistent finding, being present in over 99 % of the dried specimens examined[18]. A recent retrospective study analysed 460 CT scans and concluded that the lingual foramen in the anterior mandible is a consistent finding irrespective of the age and gender of the patient.[19] Similarly, in this study, a single midline mandibular vascular canal was observed in all the samples analyzed.

*Dimensions of MLVC:*

To determine the risk of bleeding, it is important to analyze the vascularity of the anterior mandible. Doppler ultrasonography is a reliable method of assessing risk factors associated with vascularity as it measures blood flow in real time. Lustig et al studied the diameter of the sublingual artery anastomosis and volume of blood entering the mandible in 20 healthy volunteers. It was observed that the diameter of the sublingual artery ranged from 0.18-1.8mm, whereas the blood volume ranged from 0.7-3.7ml/min[18]. The results of the present study are not in agreement with the above . In the present study the blood volume ranged between 2.8 and 17 ml/min in edentulous patients and 3.6 and 13.2 ml/min in the dentate patients (Table 1). This variation could be due to the different age groups and populations of the subjects analyzed. Similarly, it was observed that the diameter of the MLVC as studied by CBCT ranged from 0.7-1 mm in the control group, and between 0.5 – 1 mm in the group ED (Table 1). A similar range of MLVC was noted by Babiuc et al and Gahleitner et al [20, 21].

*Assessment of correlation between blood volume and MLVC :*

No study in the literature has correlated the volume of blood entering the mandible and the diameter of the sublingual artery anastomosis (as evaluated during Doppler ultrasonography) to the dimensions of the MLVC as observed on the CBCT. In this study, overall a statistically significant positive correlation was noted between the diameter of the MLVC and the blood volume and blood velocity. However on intergroup comparison, a stronger positive correlation was observed in dentate patients as compared to edentulous patients (Table 2 and 3). These findings indicate that in dentate patients the amount of blood flow correlated better with the diameter of the MLVC (Table 2). However, there was no statistically significant difference noted between the diameter of the MLVC and the blood flow in dentate and edentulous subjects (Table 2 and 3) .

Similarly, a positive correlation was noted between the diameter of the foramen as observed on the CBCT and the volume of blood entering the lingual foramen (Table 2 and 3). Although Doppler ultrasonography helps in determining the blood volume in real time, from this study, it was observed that CBCT can serve as a fairly accurate guide for determining the dimension of the artery entering the mandible along with the blood volume. As CBCT is commonly used for planning implant surgeries, it can, therefore, be inferred that clinicians should note the diameter of the foramen on the CBCT as it can predict the diameter of artery along with its blood flow into the anterior mandible.

*Correlation of Blood volume and age:*

Several reports have been published analyzing the correlation between age changes and vascularity of the mandible. Ethunandhan et al analyzed central blood flow of the mandible using Doppler sonography in age groups ranging from 20-60 years. The variables analyzed in this study were the patency of the artery, the velocity of blood flow, pulsatility index. The authors reported that the velocity, flow, and pulsatility of the artery decreases with increasing age[21].

Similarly, in a study by Eiseman et al, ultrasound measurement of arterial supply to the mandible was performed in patients of different age groups. In this study, a strong sublingual artery pulsation was noted in all the individuals belonging to the age group of <65 years. However, only 65% of subjects showed strong pulsation signals in the age group of >65 years. This study reported an age-related decrease in blood supply[22]. The results of the current study are contradictory to the results of the above-mentioned studies. In the present study, no statistically significant differences in blood volume was noted between the group ED and group DE (Table 2 and 3).

Pogrel et al studied the patency of the inferior alveolar artery by performing an arteriographic assessment in the edentulous mandible. They observed that there was no significant difference in the patency of the artery in edentulous and dentate individuals[24]. Haesman et al analyzed the patency of the inferior alveolar artery in varied age groups and observed that the patency of the artery was unaffected by age[25].

In the present study MLVC was a consistent finding in all the patients irrepective of the age and the status of the dentition. Therefore, careful evaluation of the lingual vascular canal should be done, prior to implant surgery in the midline region of the anterior mandible irrespective of the age group. It is important for clinicians to locate the lingual vascular canal and measure its diameter, specifically when planning implants in the anterior mandible. The authors strongly suggest that, prior to implant surgery clinicians should measure the distance between the lingual foramen and the alveolar ridge. In cases of immediate implant placement, a clinician should be cautious as the implants are placed deeper than the natural socket and this may encroach upon the lingual foramen[26]. Surgery in the anterior mandible must always be done with extra caution as the chances of haemorrhage are high due to anastomoses of blood vessels from incisive and mandibular canals[26]. Furthermore, understanding the course of these canals may help clinicians asses the spread of tumours in the lingual cortex region[27].

The limitation of this study is the small sample size. Studies evaluating different locations of the lingual foramen (medial and lateral) in different age groups with larger sample size should be undertaken in the future.The results of the present study should be carefully intrepreted as correlation does not necessarily mean causation and hence studies with higher sample size should be performed.

## Conclusion:

This study reaffirms that the MLVC is a consistent finding in the anterior mandible and has a rich vascular supply independent of age and status of the dentition.

Implant length should be selected carefully in the anterior mandible as perforation of the lingual foramen may lead to haemmorhage during the surgery. Pre-operative CBCT scans are recommended prior to implant placement in the anterior mandible to detect the presence, position, size of the lingual vascular canal) in the median region of the mandible. Clinicians should be aware of these anatomic structures and their possible implications. Studies evaluating the course and communications of the lingual foramen in the anterior mandible should be  performed in the future.

Conflict of interest:

The authors report no conflict of interest

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Abbreviations:

CBCT: Cone Beam Computed Tomography

MLVC: Mandibular Lingual Vascular Canal

USG: Ultra Sonography

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**Figure Legends:**

Figure 1: Axial section of CBCT depicting presence of MLVC of greater diameter

Figure 2: Sagittal section of CBCT depicting presence of MLVC of greater diameter

Figure 3: Axial section of CBCT depicting presence of MLVC of lesser diameter

Figure 4: Sagittal section of CBCT depicting presence of MLVC of lesser diameter

Figure 5: Determination of blood flow on USG in a patient having high velocity of blood flow.

Figure 6: Determination of blood flow on USG in a patient having low velocity of blood flow.

Figure 7 : Correlations between the diameter of the MLVC (observed on CBCT) and the diameter of the artery (observed in USG) irrespective of Dentate and Edentulous group

Figure 8: Intergroup Comparison of diameter of MLVC, Anastomosing artery, Blood volume and velocity

**Table Legends:**

Table 1: Bivariate Correlations irrespective of Dentate and Edentulous group

Table 2: Bivariate correlation in Dentate group

Table 3: Bivariate correlation in Edentulous patients

Table 4: Inter-group Comparison of variables using t test

**Tables:**

Table 1: Bivariate Correlations irrespective of Dentate and Edentulous group

| Parameter | N=20 | Diameter of the artery | Velocity | Volume |
|---|---|---|---|---|
| Diameter of MLVC | Pearson Correlation | .290 | .447* | .447* |
| | Sig. (2-tailed) | .215 | .048 | .048 |
| | N | 20 | 20 | 20 |
| Volume Doppler | Pearson Correlation | .138 | .994** | 1 |
| | Sig. (2-tailed) | .563 | .000 | NA |
| | N | 20 | 20 | 20 |
| Velocity Doppler | Pearson Correlation | .137 | 1 | .994** |
| | Sig. (2-tailed) | .566 | | .000 |
| | N | 20 | 20 | 20 |
| Diameter of the artery | Pearson Correlation | 1 | .137 | .138 |
| | Sig. (2-tailed) | | .566 | .563 |
| | N | 20 | 20 | 20 |

* = statistically significant difference (*P*>0.05),N= number of subjects

Table 2: Bivariate correlation in Dentate group

| | N=10 | Diameter of the artery | Velocity | Volume | Diameter of MLVC |
|---|---|---|---|---|---|
| Diameter of MLVC | Pearson Correlation | 0.563 | 0.590 | 0.616 | 1 |
| | Sig. (2-tailed) | 0.09 | 0.07 | 0.06 | NA |
| | N | 10 | 10 | 10 | 10 |
| Volume Doppler | Pearson Correlation | 0.16 | 0.98** | 1 | 0.62 |
| | Sig. (2-tailed) | 0.65 | 0.000 | NA | 0.06 |
| | N | 10 | 10 | 10 | 10 |
| Velocity Doppler | Pearson Correlation | 0.18 | 1 | 0.98** | 0.59 |
| | Sig. (2-tailed) | 0.63 | NA | .000 | 0.07 |
| | N | 10 | 10 | 10 | 10 |
| Diameter of the artery | Pearson Correlation | 1 | 0.18 | 0.163 | 0.56 |
| | Sig. (2-tailed) | NA | 0.63 | 0.65 | 0.09 |
| | N | 10 | 10 | 10 | 10 |

**= Statistically significant difference, Na= Not Applicable, N= number of subjects

Table 3: Bivariate correlation in Edentulous patients

| | N=10 | Diameter of the artery | Velocity | Volume | Diameter of MLVC |
|---|---|---|---|---|---|
| Diameter of MLVC | Pearson Correlation | 0.27 | 0.39 | 0.38 | NA |
| | Sig. (2-tailed) | 0.44 | 0.27 | 0.28 | NA |
| | N | 10 | 10 | 10 | 10 |
| Volume Doppler | Pearson Correlation | 0.15 | 1.00** | 1 | 0.38 |
| | Sig. (2-tailed) | 0.68 | 0.000 | NA | 0.28 |
| | N | 10 | 10 | 10 | 10 |
| Velocity Doppler | Pearson Correlation | 0.15 | 1 | 1.00** | 0.39 |
| | Sig. (2-tailed) | 0.68 | NAS | 0.00 | 0.27 |
| | N | 10 | 10 | 10 | 10 |
| Diameter of the artery | Pearson Correlation | NA | 0.15 | 0.15 | 0.27 |
| | Sig. (2-tailed) | NA | 0.68 | 0.68 | 0.44 |
| | N | 10 | 10 | 10 | 10 |

**=Statistically significant difference, Na= Not applicable, N= number of subjects

Table 4: Inter-group Comparison of variables using t test

| Parameter | Groups | N | Mean | Std. Deviation | Std. Error Mean | *P* value of t test |
|---|---|---|---|---|---|---|
| Diameter of MLVC on CBCT (mm) | ED | 10 | 0.76 | 0.20 | 0.62 | 0.194# |
| | DE | 10 | 0.85 | 0.11 | 0.34 | |
| Diameter of the anastomosing artery (mm) | ED | 10 | 0.88 | 0.18 | 0.59 | 0.480# |
| | DE | 10 | 0.82 | 0.19 | 0.59 | |
| Velocity of blood (cm/s) | ED | 10 | 13.79 | 7.89 | 2.50 | 0.666# |
| | DE | 10 | 15.10 | 5.32 | 1.68 | |
| Volume (ml/min) | ED | 10 | 8.26 | 4.74 | 1.50 | 0.731# |
| | DE | 10 | 8.90 | 3.29 | 1.04 | |

# = non-significant difference ($P$>0.05),N= number of subjects

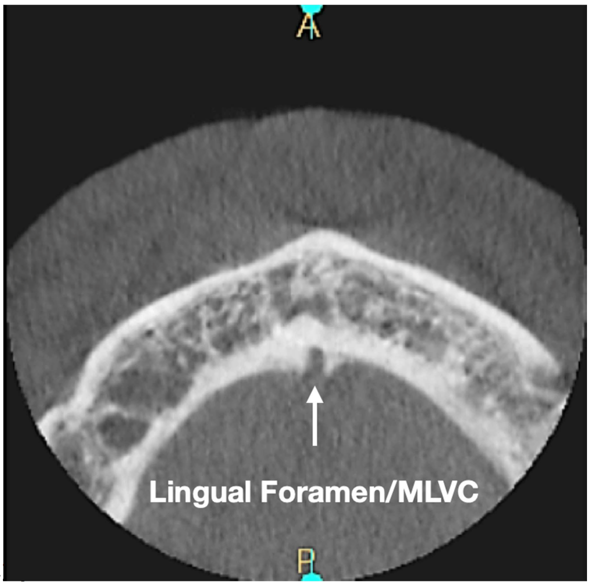


Figure 1: Axial section of CBCT depicting presence of MLVC of greater diameter

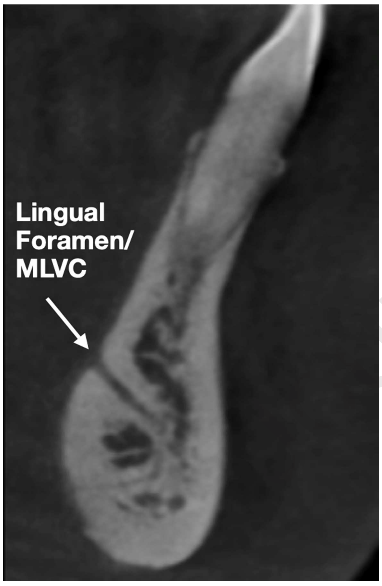


Figure 2: Sagittal section of CBCT depicting presence of MLVC of greater diameter

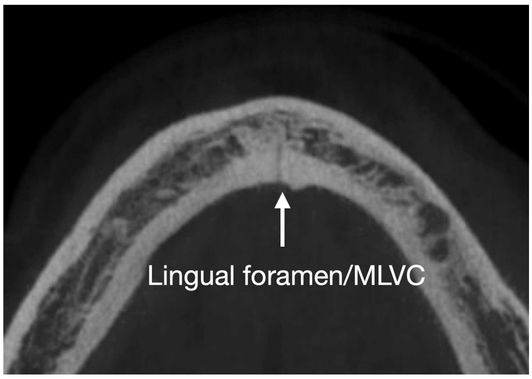


Figure 3: Axial section of CBCT depicting presence of MLVC of lesser diameter

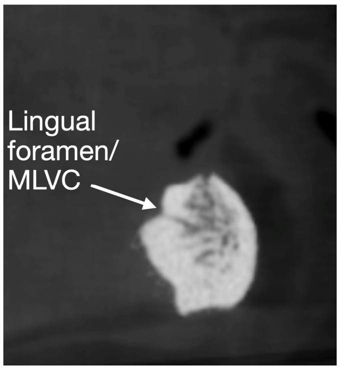


Figure 4: Sagittal section of CBCT depicting presence of MLVC of lesser diameter

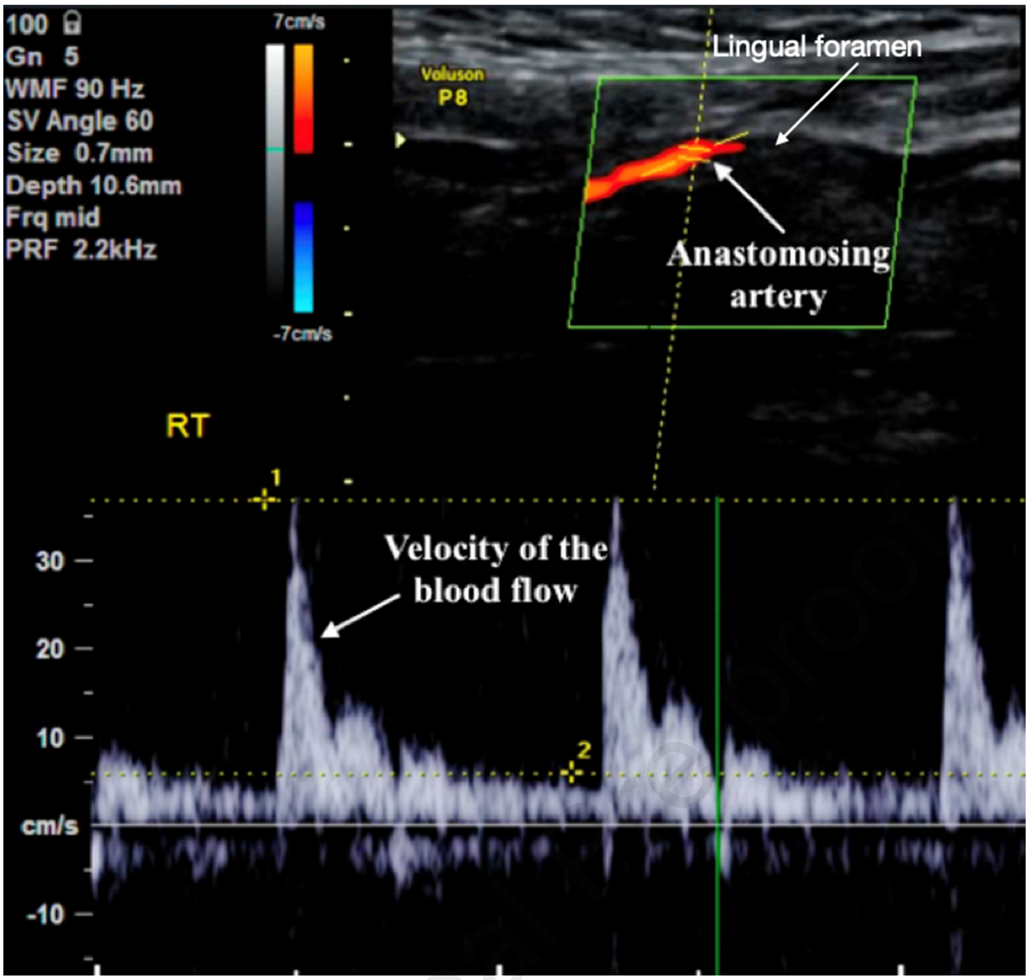


Figure 5: Determination of blood flow on USG in a patient having high velocity of blood flow.

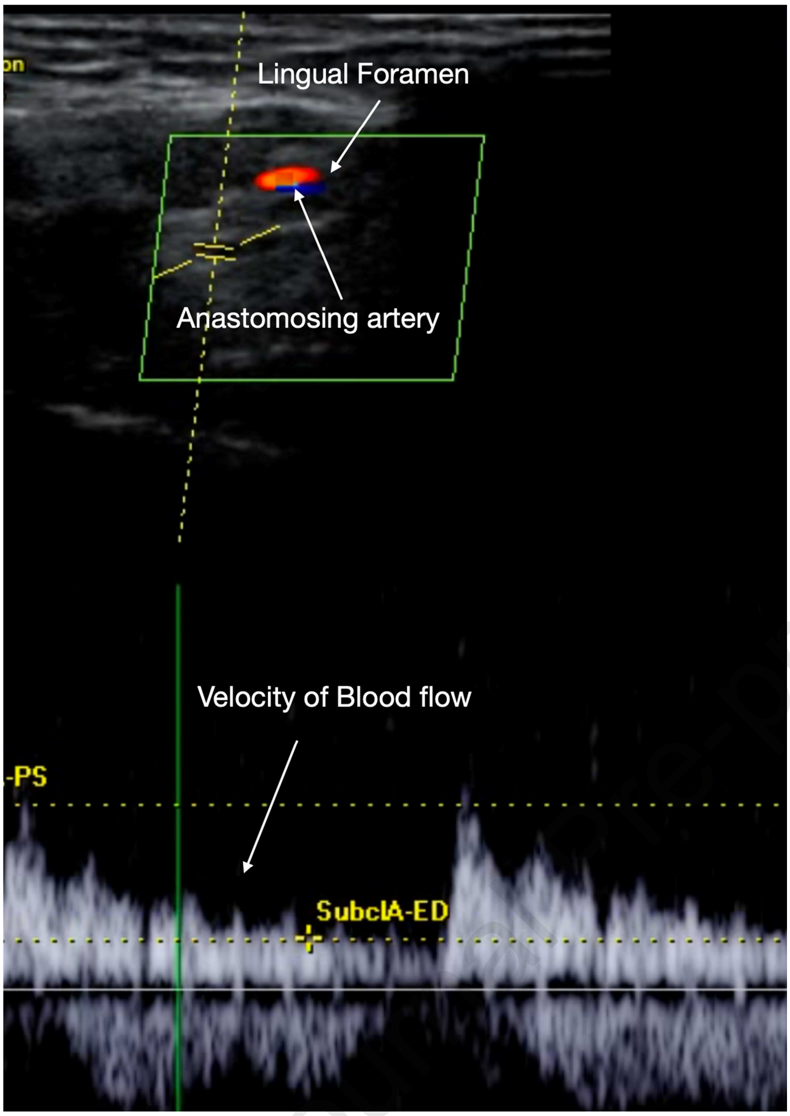


Figure 6: Determination of blood flow on USG in a patient having low velocity of blood flow.

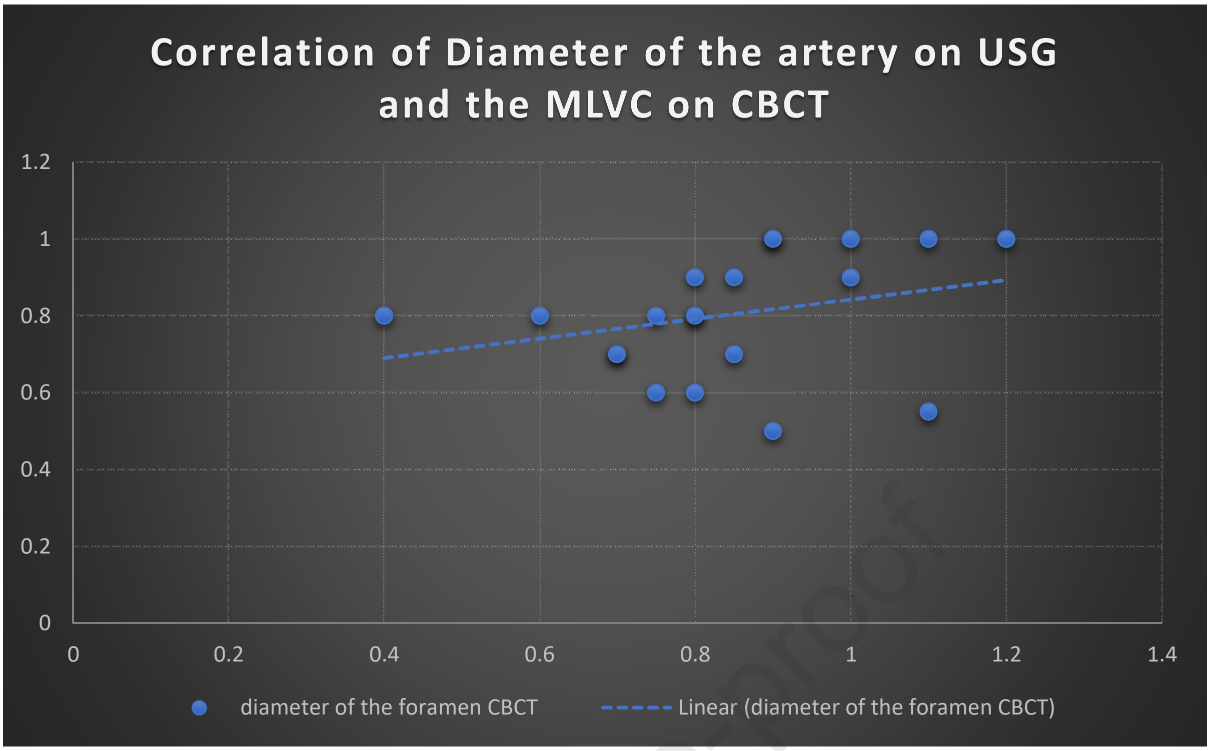


Figure 7 : Correlations between the diameter of the MLVC (observed on CBCT) and the diameter of the artery (observed in USG) irrespective of Dentate and Edentulous group

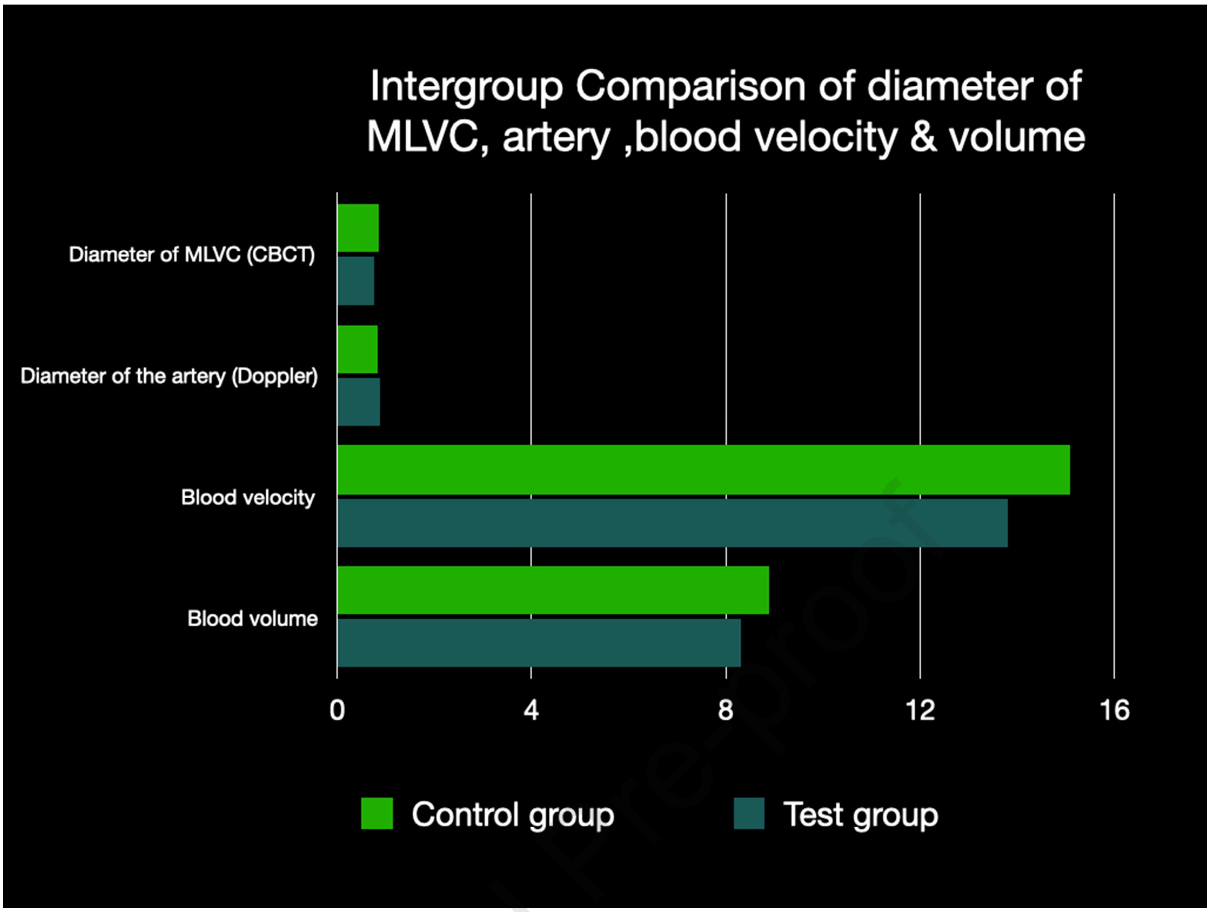


Figure 8: Intergroup Comparison of diameter of MLVC, Anastomosing artery, Blood volume and velocity